1.2 Mariene ecosystemen en biodiversiteit

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2.1 An aquatic home

From space, the Earth appears blue because water dominates the surface of our planet. There are five **oceans** on Earth today: the Arctic, Atlantic, Indian, Pacific and Southern. These oceans cover approximately 70% of the globe and their marine ecosystems are crucial for life on Earth. Oceans are where life evolved more than 3.5 billion years ago and they are home to an enormous biodiversity of sea creatures.

The interface between the oceans and the land has also proved crucial to shaping the planet we live on. Competition within life in the oceans, as well as changes in its temperatures and salinity, propelled some marine plants and animals to start colonising the land over 425 million years ago. The **seas** are where the oceans and land meet, producing a variety of coastline habitats (such as sandy, rocky, muddy). Marine biologists have also investigated the estuarine interface, where seas extend inland to meet the mouth of a river. In **estuaries** fresh water and seawater are mixed by the daily and seasonal rhythm of tides. Many marine organisms start their life here before venturing out to spend their adult life in the ocean.

The term ecology is derived from the Greek word 'oikos' meaning 'house'. Marine ecology is the study of marine organisms in their homes or habitats. Marine ecologists study the connections between marine organisms and their environments and aim to understand the factors that control the distribution and abundance of life in the oceans. To do this, it is important to understand the range of relationships between organisms. Ecologists also strive to understand how marine organisms are adapted to their aquatic environment and how both they and humans can alter that environment.

KEY TERMS

Ocean: a continuous mass of seawater on the Earth's surface, its boundaries formed by continental land masses, ridges on the ocean floor or the equator

Sea: a continuous mass of seawater on the Earth's surface, part of the ocean, that is partially enclosed by land, so seas are found where the ocean and land meet

Estuary: a partially enclosed, tidal, coastal body of water where fresh water from a river meets the salt water of the ocean

2.2 Fundamental principles of marine ecology

Ecosystems

Life on Earth can be divided into subunits called **ecosystems**. An ecosystem is all the living organisms in an area plus the non-living environmental factors that act on them.

The **biotic** components of an ecosystem are the living factors, such as producers, consumers and decomposers. Biotic components also include feeding relationships, for example predator–prey relationships, which can be shown as food chains and webs. The **abiotic** components of a marine ecosystem are the environment's geological, physical and chemical features:

- geological features include substrate type, topography and suspended sediment
- physical features include temperature, exposure to wind and sunlight wave action, tides, currents, hydrostatic pressure, light intensity and wavelength
- chemical features include organic nutrients, pH, salinity, oxygen, carbon, nitrogen and phosphorus.

KEY TERMS

Ecosystem: the living organisms and the environment with which they interact

Biotic: the living parts of an ecosystem, which includes the organisms and their effects on each other

Abiotic: the environment's geological, physical and chemical features, the non-living part of an ecosystem

Habitat: the natural environment where an organism lives

Habitat

A **habitat** is the natural environment where organisms live. Habitats are areas in which organisms can find food, protection, shelter and a mate. Marine environments form a range of habitats in estuaries, on the shoreline and in shallow and deep ocean water. Estuaries are brackish areas where fresh and salt water mix. Sediments from streams often settle in estuaries, creating a number of important habitats where marine species can feed and breed. These habitats include swampy areas called wetlands, mangrove forests and salt marshes.

The habitat an organism occupies can be defined by where it lives and how it moves. For example:

- planktonic organisms, such as phytoplankton and zooplankton, drift in ocean currents
- nektonic organisms, such as fish, marine reptiles and mammals, can actively swim
- benthic organisms, such as tube worms, starfish, crabs and sea cucumbers, live on the seabed.

Some organisms cross from one habitat to another during their life cycles. For example, crabs and clams both start out as planktonic larvae but become benthic adults.

Habitats are not always geographical; for example, parasitic worms live inside their host species.

Species

A **species** is defined as a group of similar organisms that can interbreed naturally to produce fertile offspring. Each species is given a name composed of two parts, both of which are in Latin. This naming system is called the binomial system of nomenclature. It was first formulated in 1736 by Carolus Linnaeus, a Swedish botanist. The first part of the name refers to the genus, and the second part refers to the species. The genus is given a capital letter, whereas the species is always lower case. In print, a binomial always appears in italic. For example, the Latin binomial name for the Galapagos penguin is *Spheniscus mendiculus*. When you write a binomial name by hand, you should underline it, for example Spheniscus mendiculus.

> **KEY TERMS**
>
> **Species:** a group of similar organisms that can interbreed naturally to produce fertile offspring
>
> **Population:** all the individuals of the same species that live at the same place and time

Population

A **population** is all the organisms of the same species that live at the same place at the same time, and are able to reproduce. For example, the squat lobsters living off Otago, New Zealand, are a population. Similarly, all the salmon in the Atlantic Ocean make up the Atlantic salmon population.

The number of individuals in any population often increases and decreases. Population increases are caused by reproduction or by new individuals joining the population area. Population decreases are caused by death or by individuals leaving the population area.

The largest population that can be sustained by the available resources is called the carrying capacity. If some resources are less than optimal, or get completely used up, they are called limiting factors and result in reduced growth in the population. Limiting factors can be either biotic or abiotic. Biotic limiting factors include competition and predation. Abiotic limiting factors affect growth, survival and reproduction, and include living space, food, water temperature, pH and light intensity.

Community

A **community** is an association of all the different populations of species occupying a habitat at the same time. An example is the mollusc community on a Californian rocky shore, which would include all the different species of molluscs living in this habitat. Biomes are communities that extend over large areas of the globe and are classified according to the predominant vegetation. Marine biomes include intertidal, rocky, sandy and muddy shores, coral reefs and the seabed. Each biome has a characteristic community.

Biodiversity

Biodiversity describes the enormous variation in organisms living on the Earth. Life on Earth evolved in the marine environment, the seas and oceans, which have an extremely high biodiversity.

> **KEY TERMS**
>
> **Community:** all the different populations occupying a habitat at the same time
>
> **Biodiversity:** a measure of the numbers of different species present
>
> **Ecological niche:** the role of a species within an ecosystem

Ecological niche

Ecological niche is defined as the role of a species within an ecosystem. The term also takes into account interrelationships with other organisms.

- Feeding relationships: for example, both sperm whales and killer whales are top predators. Sperm whales consume predominantly squid, whereas killer whales consume a wider variety of prey, including elephant seals and baleen whales. These two species of whale therefore occupy different ecological niches.

- Spatial relationships: two species may have the same feeding relationships but occupy that niche in different parts of the ocean. For example, if a prey species is found throughout the water column, one predator may feed on it in the surface photic zone (where there is light) while another feeds deeper down in the aphotic zone (where there is no light).
- Temporal relationships: two species may have the same feeding relationships but occupy the niche at different times, for example if a prey species is found in the same location throughout each day, one predator may feed at night (nocturnal) while another feeds in the daytime (diurnal).

2.3 Symbiosis within marine ecosystems

Symbiosis literally means 'living together'. The term refers to an interspecies relationship between two or more organisms from different species living in close physical association. The smaller partner in the symbiosis is called the symbiont and the larger one is called the host.

There are many forms of symbiosis including:

- **mutualism**, when both species benefit from the relationship
- **parasitism**, when one organism (the parasite) benefits at the expense of the host.

Other types of interspecies relationship include:

- **competition**, when both species are negatively affected by trying to fill the same ecological niche
- **predation**, feeding that involves hunting, killing and eating another animal.

KEY TERMS

Mutualism: a relationship between two different organisms where both organisms benefit

Parasitism: a relationship between two organisms where the parasite obtains benefit at the expense of the host

Competition: a relationship between two organisms where both species are negatively affected by trying to fill the same ecological niche

Predation: a relationship between two organisms where a predator hunts, kills and eats a prey animal.

Marine mutualism

Examples of marine mutualism include:

- coral and zooxanthellae
- chemosynthetic bacteria and tube worms
- cleaner fish and shrimps and their hosts.

Coral and zooxanthellae

The tissues of corals are host to symbiotic single-celled algae called zooxanthellae (see Chapter 5).

Zooxanthellae photosynthesise and provide the coral with nutrients such as oxygen and glucose:

zooxanthellae photosynthesis:
carbon dioxide + water → glucose + oxygen

As the coral grows, it respires aerobically and provides the zooxanthellae with the carbon dioxide required for photosynthesis:

coral polyps aerobic respiration:
glucose + oxygen → carbon dioxide + water

The zooxanthellae are provided with a safe habitat with a large surface area for maximum absorption of light. They also obtain other minerals from the coral's waste products: nitrogenous compounds are used to make proteins, ATP and DNA, and phosphates are used for DNA, ATP and membranes.

Chemosynthetic bacteria and tube worms

Tube worms (for example *Riftia* and *Tevnia* species) are associated with deep-sea vents (see Chapter 3). They live in the 'midnight' or aphotic zone where there is no light. Because there is no light, photosynthesis is not possible so photoautotrophic producers cannot survive in this zone. Tube worms have followed a very different evolutionary pathway compared with photoautotrophic producers. They host colonies of chemosynthetic bacteria that produce organic matter from the chemicals available at deep-sea vents. These symbiotic chemosynthetic bacteria live in an organ inside the tube worm called the trophosome. The plume at the tip of a tube worm takes in hydrogen sulfide, carbon dioxide and oxygen. Carbon dioxide and hydrogen sulfide are carried in the blood of the tube worm to the chemosynthetic bacteria in the trophosome (Figure 2.1).

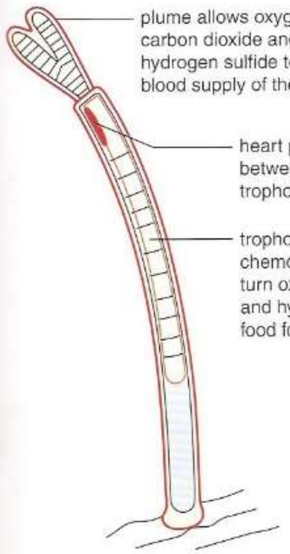

Figure 2.1. Chemosynthetic bacteria and tube worm mutualism.

In this way the chemosynthetic bacteria gain a safe environment and nutrients while the tube worms use the organic matter for cellular respiration to create the ATP energy they require to grow. The tube worms form part of the food chain for other organisms colonising the vent, such as polychaete worms, octopuses, giant clams, mussels, limpets, crabs and vent fish. Eventually, a complex community consisting of many different species is established.

Cleaner fish, shrimps and grouper

Cleaning stations are often located on the top of a coral head. Reef fish, sea turtles and sharks congregate to have parasites removed by numerous species of cleaner fish (especially wrasses and gobies) and cleaner shrimps. When the host animal approaches a cleaning station, it opens its mouth wide as a signal to the cleaner species. The cleaner species then remove and eat the parasites from the host's skin, mouth and gills. The cleaners benefit by gaining nutrients from the dead skin and parasites that they remove. They also gain protection from predators while they are cleaning. The host fish benefit from reduced infection.

Other examples of cleaning mutualism include:

- pilot fish cleaning sharks
- Pacific cleaner shrimps and bluesteak cleaner wrasses cleaning eels.

Marine parasitism

Parasitism is a relationship in which the parasites obtain benefit at the expense of the host.

Finding the next host is paramount for a parasite, and a large portion of a parasite's energy is used for reproduction. Parasites can be divided into two main groups: ectoparasites and endoparasites.

Ectoparasites

Ecotoparasites live on the outside of their host. The salmon louse is a species of copepod that is an ectoparasite on Pacific salmon (Figure 2.2). The lice attach to the skin, fins and gills of juvenile and adult salmon, and feed off the mucus or skin. The parasite can be fatal to juvenile salmon. For adult salmon, the lice can carry diseases between wild and farmed salmon (for example infectious salmon anemia, which can lead to the collapse of fish farms).

Other ectoparasitic copepods feed on the body fluids of flying fish and spread disease. Others attach to the eyes of Greenland sharks and cause inflammation, which reduces the shark's vision and its ability to survive and reproduce.

Figure 2.2. Fish lice on salmon.

Endoparasites

Endoparasites live inside their host, for example in the digestive system, attached to gills or in muscle tissue. They are considered to be parasites because they may weaken the host individual. Nematodes or roundworms are common endoparasites in tuna (Figure 2.3).

Another example of an endoparasite is the small tapeworm that derives food and shelter by living in the guts of whales.

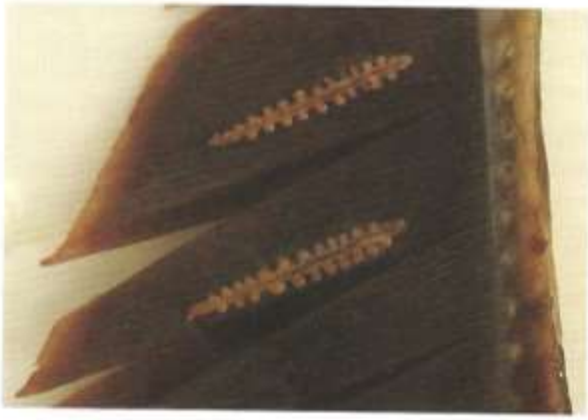

Figure 2.3. Endoparasites living on the gills of a tuna.

2.4 Feeding relationships

Producers

Producers provide food for virtually all other organisms in food chains and food webs. As autotrophs, they are 'self-feeders' and synthesise organic 'food' from simple inorganic compounds and an energy source. There are two types of producer:

- **photoautotrophs**, which use light energy
- **chemoautotrophs**, which use chemical energy.

KEY TERMS

Producer: an organism that can produce its own food energy

Photoautotroph: a producer that uses light energy to produce its own food energy

Chemoautotroph: a producer that uses chemical energy to produce its own food energy

Photoautotrophs

Photoautotrophs use pigments (for example chlorophyll) to trap light energy from the Sun, in the light-dependent stage of photosynthesis. Marine photoautotrophs include seagrass, mangroves, seaweed, kelp, cyanobacteria and phytoplankton. Phytoplankton include diatoms and dinoflagellates and are essential to life on Earth because they produce half of the world's oxygen and are a major sink for carbon dioxide. Diatoms are single-celled organisms with a silicon shell. Dinoflagellates can form enormous ocean blooms or red tides that are sometimes visible from space.

Chemoautotrophs

Chemoautotrophs use energy from the oxidation of sulfur in hydrogen sulfide to make their own food energy. Aerobic chemoautotrophs (such as mutualistic bacteria that live in tube worms) need oxygen, whereas anaerobic chemoautotrophs (such as bacteria that live in deep-sea vent sediment) do not need oxygen. Chemoautotroph producers will be covered in greater details in Chapters 3 and 6.

aerobic chemosynthesis $CO_2 + H_2O + H_2S \rightarrow (CH_2O) + H_2SO_4$

anaerobic chemosynthesis $CO_2 + 6H_2 \rightarrow (CH_2O) + CH_4 + H_2O$

SELF-ASSESSMENT QUESTIONS

1 Using the following symbols, complete Table 2.1 showing different interspecies relationships.

- 0, species is unaffected
- –, species is harmed
- +, species benefits

	host	symbiont
mutualism		
parasitism		
competition		
predation		

Table 2.1. Different interspecies relationships.

2 Name and explain the main similarity and difference between the two ways that producers can synthesise food energy.

3 Concentrations of phytoplankton are lower in Antarctica's Southern Ocean than oceans closer to the equator. How might the abiotic conditions of the Southern Ocean inhibit photosynthesis?

Consumers

The term **consumer** refers to an organism that obtains its energy requirements by feeding on other organisms. The rate at which consumers convert the chemical energy of their food into their own biomass is called secondary productivity.

Consumers include:

- predators (for example sharks) that kill and eat prey animals (for example fish)
- herbivores that eat plants (for example manatees)

- suspension feeders that filter the water for food (for example mussels)
- grazers that scrape algae (for example limpets, sea urchins and parrot fish).

Zooplankton are important consumers and include copepods, foraminifera and krill. Copepods are small herbivores that feed on diatoms. Foraminifera are single-celled animals with calcium carbonate shells. Krill are shrimp-like carnivores that feed on other zooplankton species and phytoplankton. Krill are important food sources for birds, fish, seals and baleen whales.

KEY TERMS

Consumer: an animal that feeds on other organisms to gain its food energy

Food chain: a way of describing the feeding relationships between organisms

Food web: a way of describing how food chains are interrelated in an ecosystem

Trophic level: a position in a food chain or food web

2.5 Food chains and food webs

A **food chain** shows the linear sequence of organisms feeding on other organisms. A series of interlinked food chains forms a multi-branched **food web**. In food chains and food webs, arrows represent the direction in which energy, biomass and nutrients are transferred. The term **trophic level** refers to the 'feeding level' in a food chain or web. Producers occupy the first trophic level, primary consumers occupy the second trophic level, secondary consumers occupy the third trophic level, and so on.

producer → primary consumer → secondary consumer → tertiary consumer → quaternary consumer

1st trophic level → 2nd trophic level → 3rd trophic level → 4th trophic level → 5th trophic level

Primary (first level) consumers are also known as herbivores. Secondary (second level) consumers are carnivores that feed on herbivores. Tertiary (third level) or quaternary (fourth level) consumers are carnivores that feed on carnivores. If carnivores are at the end of a food chain, they are called top predators. Organisms can be grouped into different consumer types depending on the specific food chain being discussed. For example, an omnivore feeds on plants (making it a primary consumer) and other consumers (making it a secondary consumer).

Detritivores (for example worms, fish, crabs, starfish and urchins) eat detritus (dead and decaying material). This makes it easier for decomposers (for example bacteria and fungi) to convert the organic molecules in detritus back to inorganic nutrients. Detritivores and decomposers both gain their energy from recycling the nutrients and energy in detritus (see Chapter 4).

Food webs illustrate how species feed on a number of other species so that they are not dependent on one food source. As a result, if the population of one prey species declines, alternative sources of food are still available. Food webs can also be used to illustrate the different feeding relationships that one species might have at different stages of its life cycle. For example, herring change the prey they feed on as they develop from young fish into mature adults.

Predators and their prey

Predator–prey relationships are an integral part of the niche of a consumer. A **predator** is an animal that catches, kills and eats another animal. Predators are secondary, tertiary and quaternary consumers in food chains. Marine predators include sharks as well as carnivorous fish that eat plankton (planktivores) or fish (piscivores). Predators have adaptations such as speed, agility, camouflage, teeth, poison and the ability to hunt in packs.

Prey are animals that are eaten by predators. Survival adaptations for prey animals include camouflage, defensive spines, the ability to hide in safe places and the ability to flee.

Some predator–prey relationships are an example of coevolution, where the predator and prey species have evolved together in response to changes in each other's morphology and physiology.

Predator–prey relationships are crucial for keeping a healthy balance of populations within the ecosystem. For example, without starfish (Figure 2.4a) there would be no natural predators to control the numbers of mussels, sea urchins and **shellfish**. Left unchecked, these organisms can destroy a kelp forest. Similarly, butterfly fish (Figure 2.4b)

KEY TERMS

Predator: an animal that kills and eats animals for food

Prey: an animal that is eaten by predators

Shellfish: aquatic invertebrates that are used as food, including shelled molluscs, crustaceans and echinoderms, such as bivalves, crabs, lobsters and sea urchins are herbivores that prey on marine algae growing on coral reefs. Without this crucial predator–prey relationship, the algae would overgrow the coral and limit the light reaching the zooxanthellae. This would eventually kill the coral.

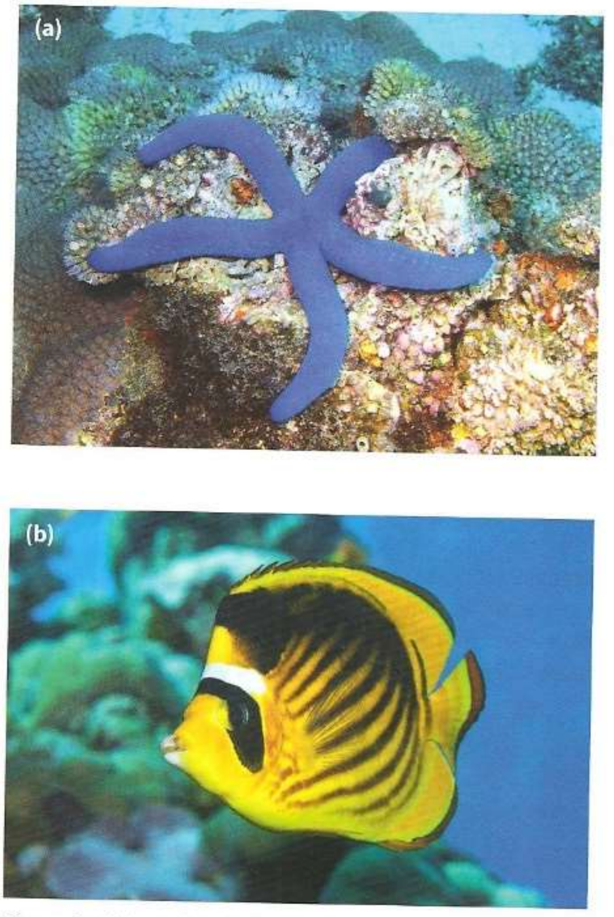

Figure 2.4. (a) Starfish; (b) butterfly fish.

Population changes in predator–prey relationships

The predator population is usually smaller than its prey population. This is because individual predators often have a larger biomass than individual prey, and there is a significant loss in energy between trophic levels.

The availability of food is a major limiting factor that affects the location and numbers of predators in an ecosystem. The spatial distribution of predators is often linked to their prey. For example, predators such as swordfish, sharks and gannets follow their sardine prey along their annual migration route. But predator and prey locations are not always linked. For example, a predator may have many alternative prey species and not closely follow prey that is a minor source of food energy.

Organisms in an ecosystem are interdependent, so when one species changes in population size, other species in the community may also be affected. When the availability of food (the number of prey organisms) increases, the number of predators also increases. This is because when predators have more food energy available, they have an increased chance of surviving and reproducing. The opposite is also true: when the number of prey decreases, the number of predators also decreases.

For example, if a fish population increases because it finds a new food source, the predator shark population also increases because the sharks have more food. If the fish population decreases because of over-fishing, the population of sharks also reduces because the sharks have less food. Conversely, if the shark population decreases as a result of sickness, the fish population would experience less predation and increase.

Lionfish

The numbers of prey and predators in interrelated populations fluctuate through time, with the number of predators lagging behind the number of prey. An example of this interrelationship can be seen between the predatory lionfish and the native Atlantic Ocean fish species that they prey on. An increase in the population of predatory lionfish causes a reduction in native fish stocks. When the fish stocks are too low to sustain the increased lionfish population, lionfish numbers begin to decrease. The drop in predatory lionfish therefore 'lags behind' the drop in numbers of its prey. A reduction in the lionfish population results in less predation of the Atlantic fish, and the fish population begins to recover. After a time lag, the rising prey population results in an increase in the predatory lionfish population. These oscillations in the predator–prey cycle continue with decreasing amplitude until a more stable ratio of predators to prey is reached (Figure 2.5).

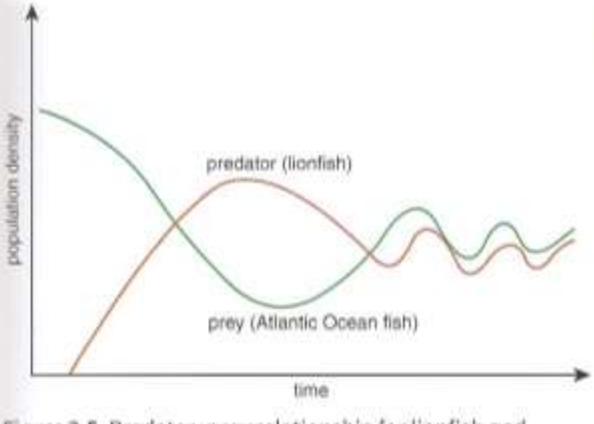

Figure 2.5. Predator–prey relationship for lionfish and Atlantic Ocean fish.

Crown-of-thorns starfish

The crown-of-thorns starfish predates corals on the Great Barrier Reef. The numbers of predators (starfish) and prey (corals) have fluctuated over a 25-year period (Figure 2.6). Between years 4 and 16, the coral population (measured by percentage cover) decreased from 52% to 6%. This led to a reduction in the relative number of starfish from 16 to 3. The drop in starfish numbers did not start until year 10: there was a time lag of 6 years between the drop in coral prey and the drop in starfish predators. The time lag resulted in a maximum number of predators as the prey population was in decline. The coral recovered between years 16 and 25 because the relative numbers of starfish were low. From 21 years, as the coral cover increased, the relative number of starfish also began to increase. Again there was a time lag between the increase in coral cover and the increase in relative number of starfish.

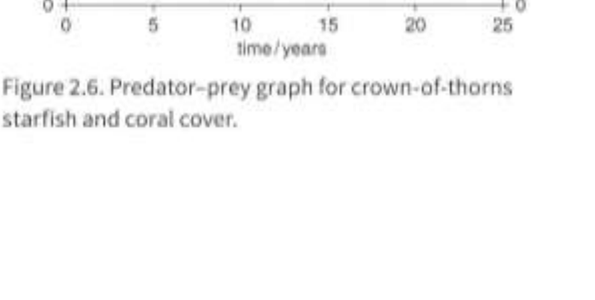

Figure 2.6. Predator–prey graph for crown-of-thorns starfish and coral cover.

KEY TERM

Keystone species: a consumer that affects biodiversity to a greater extent than would be expected from its population numbers

Keystone species

Keystone species are consumers that affect biodiversity to a greater extent than would be expected from their population numbers. Keystone species are likely to occur near the top of the food chain, although they are not necessarily the top predator. Keystone species control other species by means of predation and competition. They may also be capable of ecosystem engineering by physically modifying the habitat. Keystone species are important in conservation programmes that focus resources on maintaining such species, rather than attempting to protect and manage all endangered species in a habitat that is at risk.

Starfish are an example of a keystone species in coral reef communities. Starfish (for example *Pisaster ochraceus*) are not top predators, because they are prey for sharks, rays and sea anemones. Starfish themselves feed on a range of species, including sea urchins and mussels. If starfish are removed, mussel and sea urchin populations increase dramatically, because those species have no other natural predators. An explosion in the mussel population would drive out other molluscs (for example limpets, chitons and barnacles) by outcompeting them for the limited space available on reefs (competitive exclusion). An increased sea urchin population would feed unhindered on the coral and lead to a decrease in coral biomass. Starfish thus promote biodiversity by controlling mussel and sea urchin populations. They are key to the delicate interrelationship between other organisms within the coral reef community. Without starfish, the ecosystem biodiversity would be significantly reduced.

SELF-ASSESSMENT QUESTIONS

4 Over-fishing of cod in seas off Maine, USA, led to a population explosion of one of its prey, sea urchins. The rapid increase in sea urchin numbers nearly wiped out kelp forests in the area, the habitat for lobsters. Predict and explain what would consequently happen to the lobster population.

5 Sea urchins are considered a delicacy in many parts of the world (for example Japan and New Zealand). How could fisherman in Maine have responded to the change in populations in question 4?

Figure 2.10 A 'bait ball' of bluelined snapper.

2.6 Succession

The term **succession** refers to the gradual process of change that occurs in community structure over a period of time. This temporal change in the composition of species in a particular area is predictable and can be measured by ecologists. There are three stages in succession (Figure 2.11).

- Colonising stage: the first community of organisms to colonise a new habitat appears (a pioneer community).
- Successionist stage(s): stage(s) in which the biodiversity or species richness in a community increases during succession. Communities move through several different successionist stages. A seral stage is a stage when a new species successfully establishes within the community. The halosere is the entire range of communities that succeed one another at a salt-water site.
- Climax stage: a complex community of many species is finally formed. Over time, producers, consumers and decomposers change. Gradually, the community changes less and less frequently until the structure and species composition become stable. This is the climax community.

Types of succession

There are two types of succession: primary succession and secondary succession.

Primary succession occurs in newly formed habitats where there has never been a community before. The new habitat is a bare substrate with no life present. These new habitats can be natural, for example new islands formed as a result of underwater volcanic eruptions. Alternatively, the new habitats can be unnatural, as a result of human activity, for example the structure of a deep-sea oil rig.

Secondary succession occurs on sites that have previously supported a community that is now no longer there, for example because of habitat destruction caused by a cyclone or tsunami.

> **KEY TERM**
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> **Succession:** the change in community structure over time

Coral reefs

Both primary and secondary succession occur on coral reefs. Primary succession occurs as a volcano erupts and

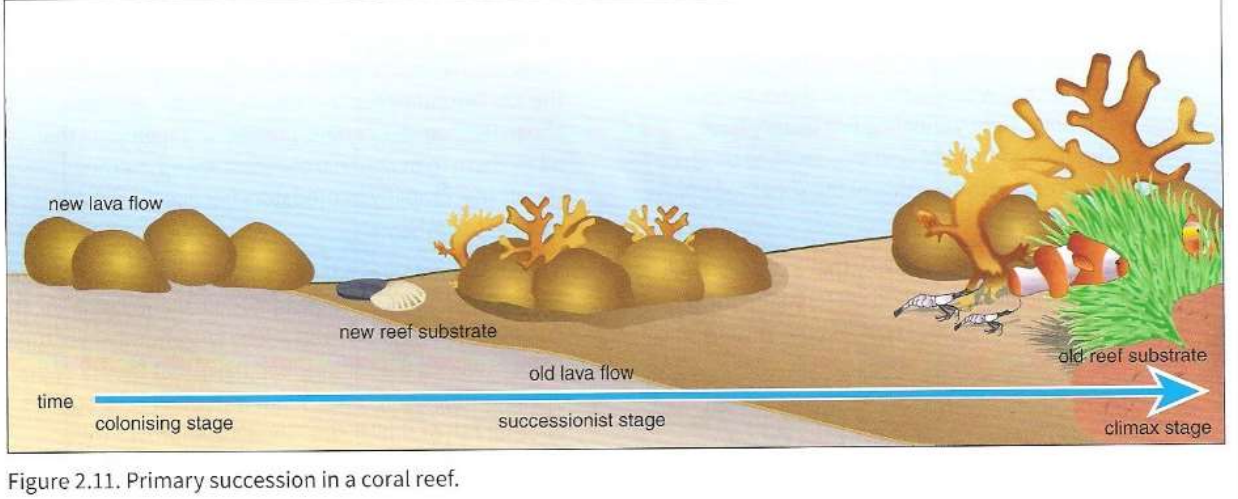


Figure 2.11. Primary succession in a coral reef.

lava creates a new habitat with no plant life (Figure 2.11). Coral is the first to colonise and grow on the lava flow, so is a pioneer species. Coral reefs also undergo secondary succession, for example after an area of the reef has been removed by deep-sea trawlers.

Hydrothermal vents

A hydrothermal vent is a gap in the Earth's surface that releases geothermally heated water.

Succession occurs around hydrothermal vents in deep oceans. Hot water forced from hydrothermal vents brings up nutrients from the rocks beneath the seabed. The first organisms to grow near the vent fluid are chemosynthetic archaebacteria. Tube worms (*Tevnia* species) are early pioneer species that inhabit a hydrothermal vent, forming symbiotic relationships with the archaebacteria. *Tevnia* is later replaced by the much larger (up to 2 m long) and faster-growing *Riftia* tube worms. The nutrients produced by the tube worms allow other organisms to colonise the vent (for example polychaete worms, octopuses, clams, limpets, crabs, mussels, hagfish and vent fish). Eventually, a complex climax community consisting of many different species is established (Figure 2.12).

Whale fall

A whale-fall community is formed when a whale dies and sinks to the ocean floor (Figure 2.13). The pioneer species of this community are detritivores, such as sharks, hagfish and amphipods. They eat the decaying flesh of the carcass. Within a year, most of the whale's flesh will have been removed. Crabs, small fish, snails and worms then eat the organic leftovers in the sediment. When only the skeleton remains, heterotrophic bacteria decompose the oils in the whale bones. The decomposition of the whale's body enriches the surrounding sediments with nutrients. Decomposition also releases compounds that serve as energy sources for chemosynthetic archaebacteria. Mussels, clams, snails, crabs and worms feed on these bacteria.

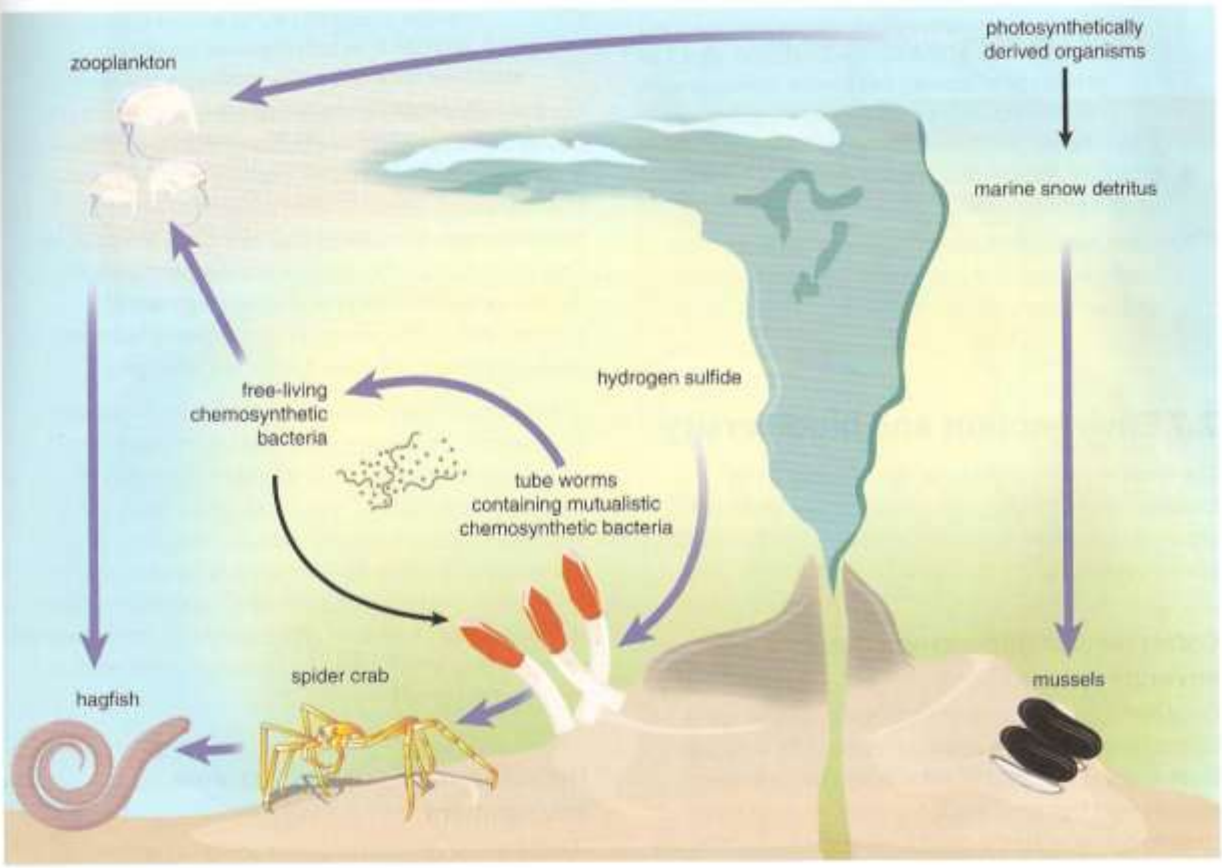


Figure 2.12. Hydrothermal vent food web.

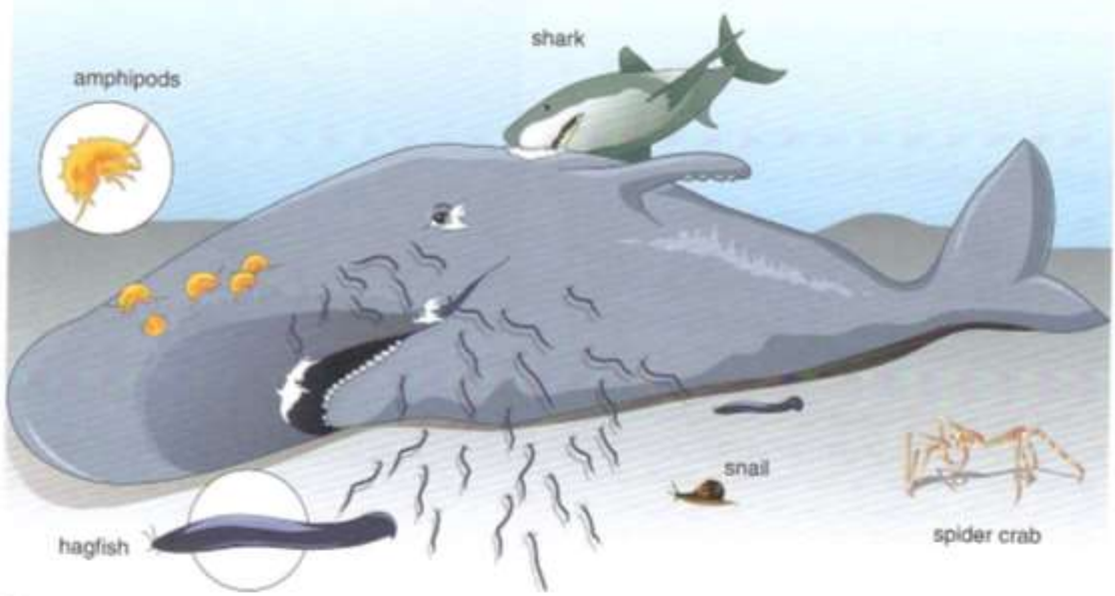


Figure 2.13. Whale-fall pioneer species.

SELF-ASSESSMENT QUESTIONS

6 Compare and contrast succession at hydrothermal vents and whale falls.

7 Using hydrothermal vent communities as an example, explain the difference between primary and secondary succession.

2.7 Environment and biodiversity

The environment is a major factor influencing the biodiversity of a habitat. Environments that are either unstable or extreme tend to have a lower biodiversity than environments that are stable and not extreme.

Coral reef: a stable and non-extreme environment

Coral reefs occupy less than 1% of the ocean floor, but contain more than 25% of known marine life. This high biodiversity is the result of a stable and non-extreme environment that provides abiotic conditions that are close to optimum for the producers. A vibrant community of producers provides the foundation for long food chains and a diverse food web.

Coral reefs are found in the photic zone in clear non-polluted shallow water. The zooxanthellae symbionts in coral are photoautotrophs, creating food energy by photosynthesis. Zooxanthellae in coral are ectothermic, so they are unable to maintain their own body temperature. They are reliant on the ambient sea temperature being constantly warm, in order to ensure a high rate of photosynthesis. This results in coral growing faster and producing greater biomass than in colder waters.

Changes in abiotic conditions can decrease biodiversity. For example, deep-water coral reefs, with lower light intensities, have less biodiversity than coral reefs in shallow waters. Human impact can also disrupt the stability of the environment's abiotic conditions and drastically reduce the biodiversity and functionality of a coral reef. Coral reefs are sensitive to rapid fluctuations in temperature (as a result of global warming) and increased sediment and toxicity (caused by coastal deforestation or agricultural run-off).

Hydrothermal vents: an extreme environment

Hydrothermal vent communities are located in an environment that is extreme because the abiotic conditions, including toxins, temperature, pH, hydrostatic pressure and light, are outside the zone of tolerance for most organisms.

The hot water from a hydrothermal vent contains dissolved minerals from the Earth's crust below the vent. As the hot vent water meets the cold oceanic water, it rapidly cools, causing the dissolved minerals to solidify. The high concentration of hydrogen sulfide gas, as well as minerals such as copper, lead, zinc and sulfur, create an environment that is toxic to most organisms. The water surrounding hydrothermal vents can reach temperatures as high as 320 °C with a pH as acidic as 2.8. To survive here, the chemosynthetic bacteria have specialised enzymes that can resist denaturing of their active sites. The bacterium *Thermus aquaticus* has an optimum temperature range of 75–80 °C.

Hydrothermal vents can occur at depths of up to 4 km. Few organisms can live at this depth because the hydrostatic water pressure may be up to 300 atmospheres. Deep hydrothermal vents are also in the aphotic zone. Producers that require light for photosynthesis are unable to grow here, so there is less energy and fewer nutrients to support consumers further up the food chain.

As few organisms are adapted to live in the extreme conditions, hydrothermal vents have a low biodiversity.

Opdracht bij les 1.2

- Kiezen uit case studies: 'Onze diepzee drogisterij' en 'Het Zuidelijke Oceaan ecosysteem‘ (volgende pagina’s)
  OF
- Vind een artikel dat de rol van een keystone soort beschrijft en vat het belang van deze soort kort samen

Les 1.2 - Onze diep-zee drogisterij

De World Health Organization (WHO) schat dat antibiotica behandelingen gemiddeld 20 jaar aan ons leven toevoegen. Maar sinds de introductie van penicilline in 1942, heeft het te veel gebruiken van antibiotica geleid tot de ontwikkeling van veel meer antibioticaresistente bacteriën. Deze onbehandelbare superbugs betekenen dat wat we vroeger makkelijk behandelbare infecties vonden, nu weer dodelijke ziekten kunnen zijn. In 2013 stierven er meer patiënten aan een resistente vorm van stafylokokken, dan aan AIDS.
Veel farmaceutische medicijnen zijn afkomstig van planten, dieren, schimmels en bacteriën. Het Europese Unie PharmSea initiatief heeft 9,5 miljoen pond beschikbaar gesteld om onderzoek te doen naar een aantal mariene organismen om uit te zoeken of deze het nieuwste supermedicijn met antibiotische, anti-kanker of anti-ontsteking eigenschappen bevatten.
Diepzee kloven zijn het grootste onontgonnen habitat ter wereld. Deze kloven worden bewoond door extremofiele organismen met unieke en ongebruikelijke biochemische eigenschappen, die ervoor zorgen dat ze in extreme temperaturen, waterdruk en pH kunnen overleven. Een aantal van de diepzee kloven wordt momenteel door mariene wetenschappers bestudeerd, zichtbaar in de figuur hieronder.

Figure 2.14. The location of deep-sea trenches, which provide habitats for extremophile organisms.

Technici laten een boorapparaat naar de bodem zakken, het duurt wel 4 uur voordat deze de bodem bereikt op 8 tot 11 kilometer diepte. De organismen in het sediment dat geboord wordt en omhoog wordt gebracht zijn gevoelig voor drukverschillen en hebben een hogedruk kamer nodig om te overleven en groeien op zeeniveau. Onderzoekers onttrekken en testen de stoffen die deze organismen produceren en testen ze op medische eigenschappen. Dermacoccus abyssi is een bacterie die uit het sediment van de Mariana Trench. Dit organisme produceert dermacozines, een nieuwe stof die kan beschermen tegen de parasiet verantwoordelijk voor de Afrikaanse slaapziekte. Mariene organismen die op de oceaanbodem leven van ondiepere wateren kunnen ook een bron voor medicijnen zijn. Zulke organismen kunnen verzameld worden door baggeren, scuba duiken of snorkelen. Zo zijn er bijvoorbeeld drie soorten Australische zeesponzen die een stof genaamd chondropsine produceren. Deze stof kan bepaalde enzymen afremmen die te maken hebben met de ontwikkeling van botkanker, Alzheimer’s, virusinfecties, diabetes en hart- en vaatziekten.

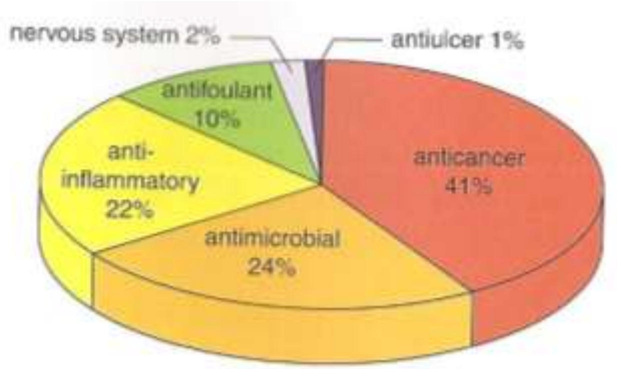


Figure 2.15. Use of beneficial chemicals derived from marine organisms.

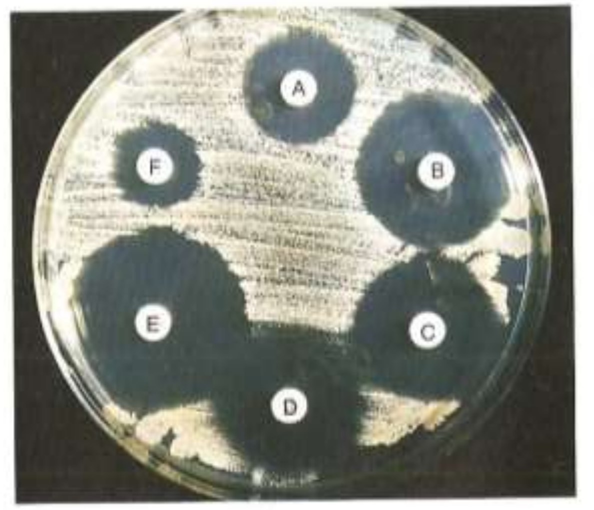


Figure 2.16. The effect of antibiotics produced by different strains of sponge-derived bacteria (A–F).

1. Waarom worden er juist in de diepzee meer organismen gevonden die bijzondere eigenschappen hebben?

2. Australische zeesponzen zijn mutualistische gastheren voor bacteriën die chondropsinen produceren. Leg uit hoe de spons en bacterie allebei voordeel hebben van het samenleven.

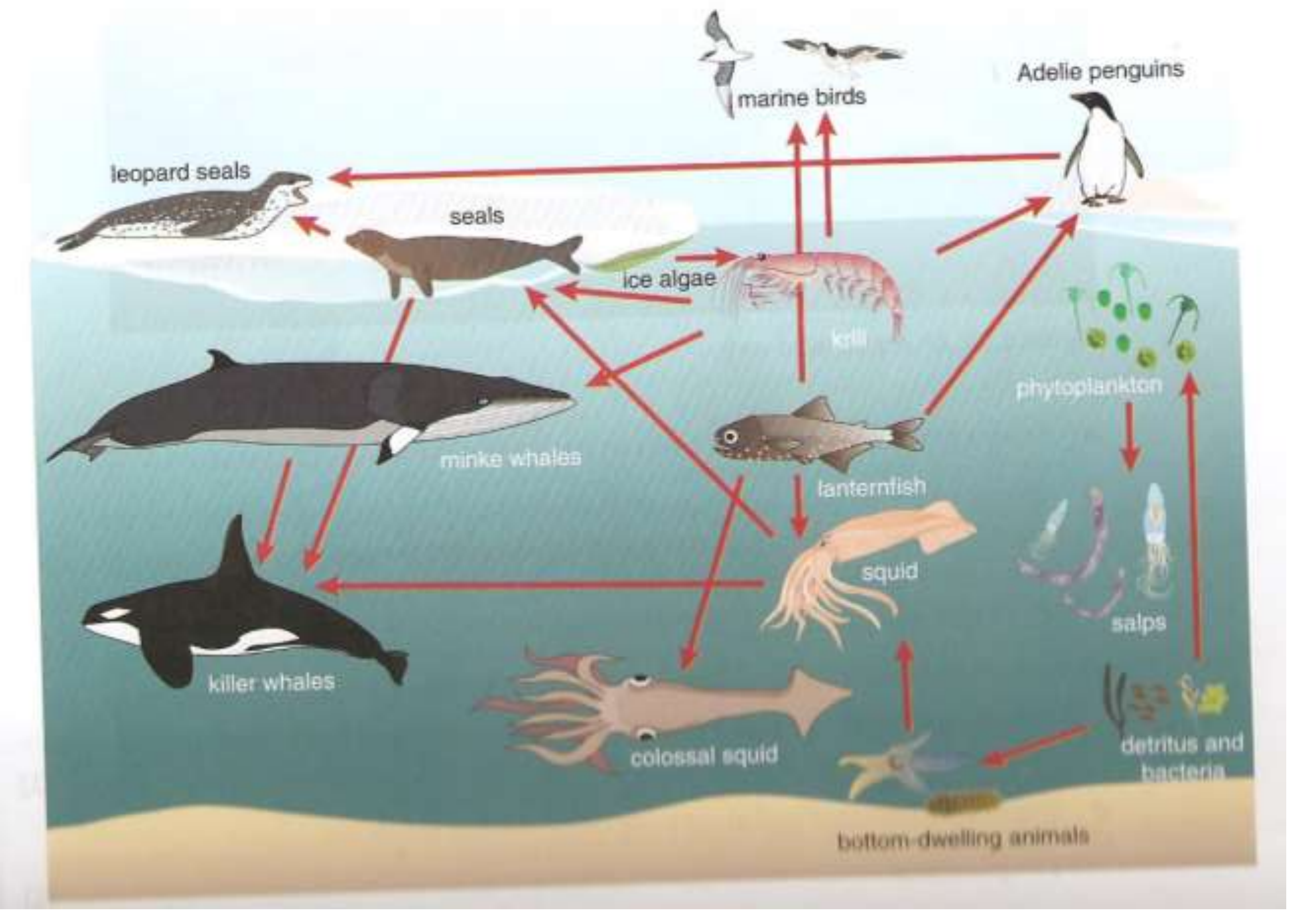
3. Figuur 2.16 laat verschillende stammen van mariene bacteriën (A-F) zien die zijn geoogst uit sponzen. Deze bacteriën produceren krachtige antibiotica tegen een aantal resistente bacteriën. Het effect van de antibiotica kan gemeten worden door de radius van de remmende zone. Een remmende zone is een gebied waar bacteriën niet kunnen groeien vanwege de productie van een antibioticum. Leg uit welke stam het meest effectief is in deze figuur.

4. Zoek op het internet nog een voorbeeld van nieuwe medische ontdekkingen uit de diepzee.

5. Waarom is het momenteel nog niet heel gebruikelijk om in de diepzee op zoek te gaan naar medische toepassingen van organismen?

Les 1.2 – Het Zuidelijke Oceaan ecosysteem

De Zuidelijke Oceaan omcirkelt Antarctica en omvat tussen 10 en 20% van het oppervlak van alle oceanen van de wereld. De Zuidelijke Oceaan is niet gelijkmatig in de productiviteit of biodiversiteit. Veranderingen in ijsoppervlak, zeebodem en stromingen zorgen voor verschillende habitats. De voedselwebben van de Zuidelijke Oceaan zijn een van de meest belangrijke ter wereld. Ze bevatten organismen van algen tot grote organismen zoals walvissen, zeehonden en pinguïns, zoals te zien is in de figuur hieronder.



Producenten in de Zuidelijke Oceaan zijn eencellige organismen die kunnen fotosynthetiseren, genaamd fytoplankton. Het water rond Antarctica is vaak bevroren en bedekt met ijs. Onder het ijs is de lichtintensiteit te laag voor de fotosynthese van fytoplankton, maar algen kunnen er wel groeien. Deze algen zijn een belangrijke voedselbron voor herbivore zoöplankton zoals krill.

Zoöplankton zijn consumenten die zich voeden met fytoplankton. Sommige soorten zijn hun hele leven plankton, anderen alleen in hun larven stadium. Wanneer het ijs smelt in de lente, vormt er een laag met minder zout water, samen met nutriënten en zonlicht. Hierdoor komt er een fytoplankton bloei, waar zoöplankton zich mee voedt en dus in aantal toeneemt. De zoöplankton is een belangrijke voedselbron voor verschillende organismen, zoals vissen, vogels, inktvis, walvissen, zeehonden en pinguïns.

Verminderd zee-ijs en de visserij zijn een bedreiging voor zoöplankton. Micro-organismen zoals bacteriën en virussen zijn ook belangrijk in het voedselweb. De bacteriën voeden zich met organische stoffen die zijn opgelost in het zeewater, en als reducenten breken zij de dode resten af en brengen daarmee anorganische stoffen terug in het voedselweb voor de groei van fytoplankton.

1. Waarom kunnen algen beter fotosynthetiseren onder het ijs dan fytoplankton?

2. Teken met behulp van de figuur een voedselketen met daarin zowel krill als een quartaire consument.

3. Waarom is zoöplankton een keystone soort voor de Zuidelijke Oceaan?

4. Klimaatsverandering zorgt voor minder zee-ijs rond Antarctica, wat een effect heeft op de pinguïn populaties. Gentoo pinguïns nemen toe in aantal, terwijl Adelie penguins afnemen. Adelie pinguïns eten krill, terwijl gentoo penguins een flexibel dieet van inktvis en vis hebben. Leg uit hoe de verschillende niches van deze pinguïn soorten hun kans op overleving beïnvloedt.

5. Minder zee-ijs resulteert in minder fytoplankton. Waarom zijn er hierdoor minder bentische soorten (die op de bodem leven)?